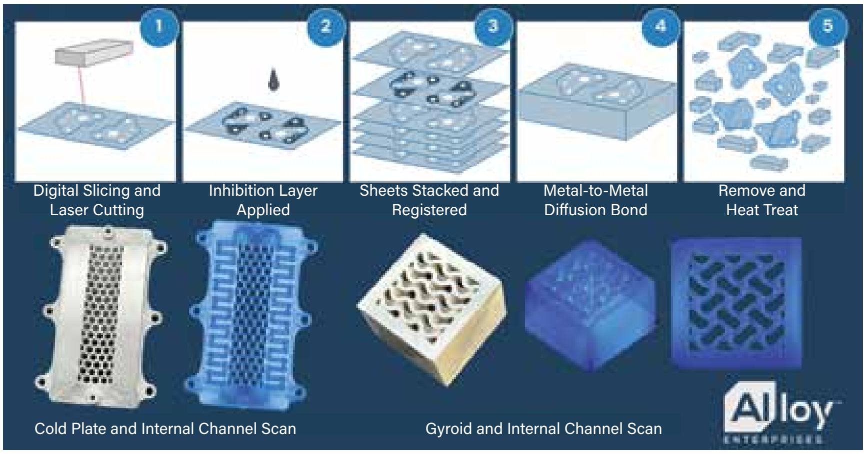
Digital Fabrication of Aluminum Components Redefines the Metal Manufacturing Industry

The demand for aluminum continues to rise in the e-mobility, heavy equipment, industrial product, and semiconductor sectors. This increase is attributed to electric vehicles and renewables, infrastructure investments, and consumers wanting eco-friendly options. Meanwhile, supply from U.S. foundries has declined significantly due to the high cost of tooling, labor shortages, and little to no capacity.

Fabrication methods need to keep pace with the speed of innovative new designs. Traditional casting is a centuries-old process that has not inherently changed in 400 years; it has long setup times and requires high production volumes to make it an economically viable option. However, the 3D printing process incurs up to 80 times the raw material costs of alternative methods, has much longer build times, produces limited throughput, and generates more than 80% waste. Powder bed fusion poses safety risks because of its explosive and inhalation hazards. Alloy Enterprises, a Boston-based tech start-up, was founded in early 2020 to address these challenges.

With funding from the U.S. National Science Foundation (NSF), Alloy developed a breakthrough "Stack Forging" digital fabrication process that produces fully dense 6061-T6 aluminum components with complex geometries, no porosity, and enclosed internal channels. Alloy's end-to-end process provides part consolidation with single-piece construction, no tooling, and no additional assembly.

Alloy's advanced technology combines a selective diffusion bonding technique with proprietary slicing software for optimized laser cutting. The Stack Forging process starts with digitally slicing the 3D model into discrete layers. Slicing is followed by laser-cutting the design into sheets from Alloy's custom feedstock. Next, an agent is selectively applied to create an inhibition layer in designated areas of the design, which acts as a mold release. To ensure tight tolerances, the sheets are stacked and registered. The sheets are then metal-to-metal diffusion-bonded together to form a solid block. Once the block is formed, the support material is removed, and the components are heat-treated for strength and hardness.



▲ The Stack Forging digital fabrication process can create components with complex geometries, no porosity, and enclosed internal channels.

Alloy's multi-functional components are fabricated to be leak tight with optimized flow, pressure drop, and performance for thermal dissipation. "Heat transfer is critical to the performance of our products; 40% improvements [in thermal management efficiency] become game-changers," says Rob Martinsen, CTO at nLIGHT, a photonics manufacturer.

Alloy's process is scalable for large and small production volumes with flexible capacity, quick turn iterations, and no minimum order quantity. Alloy components feature conformal surfaces and are engineered for optimal tensile/yield/shear strength, elongation, hardness, and thermal conductivity. The company's current build volume is 300 mm × 250 mm × 200 mm; wall thicknesses of 2–3 mm in the z dimension are possible and can be even thinner in the x-y dimension. This novel aluminum manufacturing method is ideal for thermal management, aftermarket, fluid handling, and structural applications that require lightweighting and integrated cooling. Alloy is a single-source supplier based in the U.S., offering customers supply chain optimization and sustainability.

After generating revenue with their pilot manufacturing facility, Alloy is scaling the business by building out their team and production facilities to meet customer demand. The company can produce complex aluminum components — going from evaluation, part review, finalized design, and build — in just four weeks. This start-up is not only transforming how aluminum components are made, but also fostering an inclusive culture and changing the face of manufacturing with women in leadership roles. CEP

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